is certainly a member of the group of *Dicynodontia*. Geologists will not underrate the value of this discovery in its bearing on the question of the age of the reptiliferous sandstone of Elgin.

### 3. *Report on the Fossil Plants of the Tertiary and Secondary Beds of the United Kingdom.*—See Reports, p. 396.

## *MONDAY, SEPTEMBER* 14.

The following Papers were read :—

### 1. *The Highland Controversy in British Geology : its Causes, Course, and Consequences. By* Professor Charles Lapworth, *LL.D., F.G.S.*

#### Part I.

The author gave a *résumé* of the views of the earlier geologists respecting the geological age and possible mode of formation of the Highland Metamorphic rocks, and sketched in brief the rise and progress of the controversy between Sir R. Murchison and his followers on the one hand, and Professor Nicol of Aberdeen on the other, till its temporary close in 1855 by the publication of the Highland Memoir of Murchison and Geikie. He then reviewed the re-opening of the controversy by Dr. Hicks in 1877, and the work of the Archæan geologists, up to the date of publication of Dr. C. Callaway's paper in 1883, in which Nicol's view of the great physical break between the Palæozoic rocks and the Eastern or Upper Gneissic series was shown to be correct; but the so-called Eastern Gneiss was provisionally erected into a new Archæan system, having the Arnaboll Gneiss as its lower member.

The author next gave a summary of his own views, as deduced from his personal study of the Durness-Eriboll district in 1882 and 1883, illustrating them by coloured maps and sections. He held that (exception being made of the local Torridon sandstone) the only rock-formations in the Durness-Eriboll area are, as Nicol originally contended,—(1) the Archæan or Hebridean gneiss, and (2) the Palæozoic quartzites, fucoid beds, and limestones.

There is no conformable ascending succession from the Palæozoic rocks into the Eastern Metamorphic series. The line of contact is, generally speaking, a plane of dislocation, and where this is wanting the Palæozoic rocks rest unconformably upon one of the members of the Eastern Gneiss. The present physical relations of the Eastern Metamorphic series are the effect of lateral crust-creep, by which the Eastern Metamorphic rocks have been forced over the Palæozoic rocks to the west, often for many miles. This Eastern Metamorphic series is composed of two petrological members, the *Arnaboll gneiss* to the west, and the *Sutherland schists* and gneiss to the east, having between them a series of *variegated schists* possessing characters common to both. The Arnaboll gneiss is simply the easterly extension of the Hebridean of the west. The remaining gneisses and schists of the Eastern Metamorphic series are mainly composed of remetamorphosed Hebridean, with included patches of igneous and Palæozoic material. The planes of schistosity which divide the layers of the Upper Gneissic series are not planes of bedding, but planes of dislocation. The present dip, strike, and mineralogical characteristics of these rocks have been given to them since Silurian times, by the agency of the great earth movements. In some instances the original structures of the rocks are still recognisable ; frequently, however, they are more or less obliterated, the old minerals have disappeared as such, and new minerals have been developed. The Eastern Gneissic series of this area has thus no pretension whatever to the title of a sedimentary rock-system. It is a petrological rock-massif, a metamorphic compound, composed of local elements of different geological ages. In all their essentials these views appear to agree with those worked out independently by Messrs. Peach and Horne in 1884.

## PART II.

In the second part of his paper the author gave a summary of the work accomplished among the metamorphic rocks of the Alps and Eastern Germany by Heim and Lehmann, and described the several types of rock metamorphism found in the Eriboll district, as worked out by himself.

The Arnaboll (Hebridean gneiss), can be traced stage by stage from spots where it retains its original strike and petrological characters, to others where it acquires the normal strike and mineralogical features of the ordinary Sutherland schists. The old planes of schistosity become obliterated and new ones are formed; the original crystals are crushed and spread out, and new secondary minerals (mica and quartz) are developed. The most intense *mechanical* metamorphism occurs along the grand dislocation (thrust) planes. The gneisses and pegmatites resting on that plane are crushed, dragged, and ground out into a finely laminated schist (*mylonite*; Gr. *mylon*, a mill), composed of shattered fragments of the original crystals of the rock, set in a polarising cement of secondary quartz, the lamination being defined by minute inosculating lines (fluxion lines) of kaolin or chloritic material, with secondary crystals of a micaceous mineral. Whatever rock rests immediately upon the thrust-plane, whether Archæan, Igneous, or Palæozoic, &c., is similarly treated, the resulting mylonite varying in colour and composition according to the material from which it is formed.

The variegated schists, which form the transitional zones between the Arnaboll gneiss and Sutherland mica-schists, are all essentially mylonites in origin and structure, and appear to have been formed along great dislocation planes, some of which still show between them patches of recognisable Archæan and Palæozoic rocks. These variegated schists (phyllites or mylonites), differ locally in composition according to the material from which they have been derived, and in petrological character according to the special physical accidents to which they have been subjected since their date of origin, forming frilled schists, veined schists, glazed schists, &c. &c.

The more highly crystalline flaggy mica-schists &c. which lie immediately to the east of the zones of the variegated schists, appear to have been made out of similar materials to those of the variegated schists, but to have been formed under somewhat different conditions. They show the fluxion-structure of the mylonites, but while the differential motion of the component particles seems to have been much less, the chemical change was much greater. In some of these crystalline schists (the augen-schists), the larger crystals of the original rock from which the schist was formed are still individually recognisable, while the matrix now containing them is a secondary crystalline matrix of quartz and mica arranged in the fluxion-planes. While the *mylonites* may be described as microscopic pressure-breccias with fluxion-structure, in which the interstitial siliceous and kaolinitic paste has only crystallised in part; the *augen-schists* may be described as pressure-breccias with fluxion-structure, in which the whole of the interstitial paste has crystallised out. The *mylonites* were formed along the thrust-planes, where the two superposed rock-systems moved over each other as solid masses, the *augen-schists* were probably formed in the more central parts of the moving system, where the all-surrounding pressure forced the rock to yield somewhat like a plastic body. Between these augen-schists there appears to be every gradation, on the one hand to the mylonites, and on the other to the typical mica-schists composed of quartz and mica.

Like the mylonites, the crystalline augenites and micalites present us with local differences in chemical composition (calcareous, hornblendic, quartzose, &c.) They also show corresponding structural varieties due to secondary changes (frilled, veined, glazed, &c.), as well as others due to the presence of special minerals (garnet, actinolite, &c. &c.).

## 2. *The Geology of Durness and Eriboll, with special reference to the Highland Controversy. By* B. N. Peach, *F.R.S.E., and* J. Horne, *F.R.S.E.*

With the permission of the Director General of the Geological Survey, the authors gave an outline of the geological structure of the Durness-Eriboll region, illustrated by a series of horizontal sections. They showed that the Silurian strata of Durness are arranged in the form of a basin bounded on the east side by powerful faults disconnecting them from the same series in Eriboll. The order of succession in the two areas is identical from the basal quartzites to the horizon of the Eilean Dubh limestone group. On the west side of Loch Eriboll the basal quartzites rest unconformably on the Archæan gneiss, but on the eastern shore there is conclusive evidence of the repetition of various members of the Silurian series by a remarkable system of reversed faults culminating in a great dislocation which has thrust the Archæan gneiss over the truncated edges of the quartzites, fucoid beds, serpulite grits, and basal limestone. Reference was made to the effect of these mechanical movements on the Silurian rocks and to the development of new planes of schistosity in the gneiss above the thrust plane. At intervals, small patches of the basal quartzites are met with throughout this mass of Archæan gneiss, which are abruptly truncated by great reversed faults, but in the district between Eriboll and Assynt the whole Silurian succession from the basal breccia to the lowest limestone occurs repeatedly above the first great thrust plane, separated by wedges of highly sheared gneiss. It was shown that the alteration produced by each successive displacement gradually becomes more pronounced as the observer passed eastwards across the area. The old north-west strike of the Archæan gneiss gave place to a new foliation running more or less parallel with the strike of the thrust planes; the felspathic basal quartzites and the 'pipe-rock' pass into quartz schists and mica schists, and the Silurian limestone is felted with the crushed Archæan gneiss. Reference was next made to the outcrop of the great thrust plane extending from the Whitten Head Coast far to the south, which ushers in a highly schistose series with a N.N.E. and S.S.W. strike. After describing the lithological characters and order of succession of the eastern schists, the authors stated that the new planes of foliation had been superinduced by the mechanical movements that took place between Lower Silurian and Old Red Sandstone time, and that along these new planes a rearrangement and recrystallisation of mineral constituents took place, resulting in the production of crystalline schists. Applying the knowledge thus obtained from the study of the eastern schists to the undisturbed Archæan masses, they had found conclusive evidence of similar mechanical movements in Pre-Cambrian time. Each plane of schistosity exhibits the parallel lineation like slickensides trending in the same direction over a vast area, while the minerals were oriented along these lines. From a consideration of these phenomena the authors inferred that regional metamorphism need not necessarily be confined to any particular geological period, and further that the planes of foliation or schistosity in those areas which had been subjected to regional metamorphism were evidently due to enormous mechanical movements which had induced molecular changes in crystalline and clastic rocks.

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## 3. *Preliminary Note on some Traverses of the Crystalline District of the Central Alps. By* Professor T. G. Bonney, *D.Sc., LL.D., F.R.S., Pres.G.S.*

During the past four years I have made several traverses of the Central Alps from north to south, and venture to lay before the Section the general results as bearing in some respect on the geology of the Highlands.

1. The ordinary rules of stratigraphy as learnt from most lowland districts are commonly quite inapplicable to the Alps. The most highly crystalline and the older beds often form the higher parts of a mountain region, the newer the lower. The newer beds frequently appear to underlie and dip regularly beneath the older. Gigantic folds, overturns, and overthrust faults abound. The true stratigraphy of